ECE 342
Electronic Circuits

Lecture 5
Diode Applications

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Diodes as Voltage Regulators

- **Objective**
  - Provide constant dc voltage between output terminals
  - Load current changes
  - Dc power supply changes
  - Take advantage of diode I-V exponential behavior

Big change in current correlates to small change in voltage
Voltage Regulator - Example

Assume $n=2$ and calculate % change caused by a $\pm 10\%$ change in power-supply voltage (a) with no load (b) with 1-k$\Omega$ load

Nominal value of current is:

$$I = \frac{10 - 2.1}{1} = 7.9 \text{ mA}$$

Incremental resistance for each diode:

$$r_d = \frac{nV_T}{I} = \frac{2 \times 25}{7.9} = 6.3 \Omega$$

Resistance for all 3 diodes:

$$r = 3r_d = 18.9 \Omega$$

Voltage change

$$\Delta v_o = 2 \frac{r}{r + R} = 2 \frac{0.0189}{0.0189 + 1} = 37.1 \text{ mV} \rightarrow \pm 18.5 \text{ mV} \rightarrow \pm 0.9\%$$
Voltage Regulator – Example (con’t)

When 1kΩ load is connected, it draws a current of 2.1 mA resulting in a decrease in voltage across the 3 diodes given by

\[ \Delta v_o = -2.1 \times r \]

\[ \Delta v_o = -2.1 \times 18.9 = -39.7 \text{ mV} \]
Diode as Rectifier

While applied source alternates in polarity and has zero average value, output voltage is unidirectional and has a finite average value or a \( dc \) component.
$v_s$ is a sinusoid with 24-V peak amplitude. The diode conducts when $v_s$ exceeds 12 V. The conduction angle is $2\theta$ where $\theta$ is given by

$$24\cos \theta = 12 \Rightarrow \theta = 60^\circ$$

The conduction angle is 120°, or one-third of a cycle. The peak value of the diode current is given by

$$I_d = \frac{24 - 12}{100} = 0.12 \ A$$

The maximum reverse voltage across the diode occurs when $v_s$ is at its negative peak: 24+12=36 V
Half-Wave Rectifier

(a)

(b)

(d)

Slope = \frac{R}{R + r_D}

v_S

v_D0

v_O

V_D0

v_S

v_O

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Full-Wave Rectifier

(a) Diagram of a full-wave rectifier circuit with diodes $D_1$ and $D_2$, transformer, and resistor $R$.

(b) Graph showing the input voltage $v_S$ and output voltage $v_D$ with slopes indicating the rectification process.

(c) Time-domain representation of the input and output voltages $v_S$ and $v_D$.
Bridge Rectifier

(a)

(b)
Bridge Rectifier

• Properties
  – Uses four diodes.
  – $v_o$ is lower than $v_s$ by two diode drops.
  – Current flows through $R$ in the same direction during both half cycles.

The peak inverse voltage (PIV) of each diode:

$$PIV = v_s - 2v_D + v_D = v_s - v_D$$
Peak Rectifier

Filter capacitor is used to reduce the variations in the rectifier output
Rectifier with Filter Capacitor
Rectifier with Filter Capacitor

- **Operation**
  - Diode conducts for brief interval $\Delta t$
  - Conduction stops shortly after peak
  - Capacitor discharges through $R$
  - $CR \gg T$
  - $V_r$ is peak-to-peak ripple

\[
\begin{align*}
  i_L &= \frac{v_o}{R} \quad I_L = \frac{V_p}{R} \\
  i_D &= i_C + i_L = C \frac{dv_L}{dt} + i_L \\
  v_o &= V_p e^{-t/CR} \\
  V_r &\approx V_p \frac{T}{CR} = \frac{V_p}{fCR} = \frac{I_L}{fC} \\
  i_{Dav} &= I_L \left(1 + \pi \sqrt{2V_p / V_r}\right) \\
  i_{D_{max}} &= I_L \left(1 + 2\pi \sqrt{2V_p / V_r}\right)
\end{align*}
\]
Diode Circuits - Rectification

\( V_{in} = A \sin \omega t \)

Rectification with ripple reduction.

\( C \) must be large enough so that RC time constant is much larger than period.